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Geology of

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Hecla–Kilmer Alkalic Rock Complex

District of Cochrane

Ontario Geological Survey
Study 38

by R. P. Sage

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Foreword

The Hecla–Kilmer Alkalic Rock Complex was examined as part of a project to study alkalic rock – carbonatite complexes in Ontario. The study describes the rock types and mineralogy of the complex and outlines the history of the mineral exploration efforts within the complex.

V.G. Milne

Director
Ontario Geological Survey

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CONVERSION FACTORS FOR MEASUREMENTS IN ONTARIO GEOLOGICAL SURVEY PUBLICATIONS

Conversion from SI to Imperial			Conversion from Imperial to SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
		LENGTH			
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
		AREA			
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
		VOLUME			
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
		CAPACITY			
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
		MASS			
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
		CONCENTRATION			
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy) per ton (short)	20.0	pennyweights per ton (short)
1 pennyweight per ton (short)	0.05	ounces (troy) per ton (short)

Note: Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries, published by the Mining Association of Canada in cooperation with the Coal Association of Canada.

Geology of
Carbonatite – Alkalic Rock Complexes in Ontario:
Hecla–Kilmer Alkalic Rock Complex
District of Cochrane

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1. Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto. Manuscript approved for publication by John Wood, Chief Geologist, Ontario Geological Survey, June, 1983.

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Abstract

The Hecla–Kilmer Alkalic Rock Complex lies within the Kapuskasing Subprovince of the Superior Province of the Canadian Shield. The complex is one of several alkalic complexes that occur within the north end of this subprovince.

The intrusion, which is unexposed beneath a muskeg cover, consists of essexite, ijolite, pyroxenite and nepheline syenite.

A rubidium–strontium isotopic age has been unsuccessfully attempted, however the data do suggest an early Paleozoic age for the intrusion.

Limited but unsuccessful testing of the complex for economic mineralization has been completed. The complex may warrant additional examination.

Résumé

Le complexe de roches alcalines d'Hecla–Kilmer est compris dans la sous–province de Kapuskasing de la province supérieure du bouclier canadien. Il fait partie d'un ensemble de complexes alcalins situé à l'extrémité nord de cette sous–province.

Cette intrusion, que recouvre un marécage, est composée d'essexite, d'ijolite, de pyroxénite et de syénite à néphéline.

On n'a pas pu déterminer l'âge du complexe au moyen de procédés isotopiques au rubidium–strontium, les données recueillies semblent cependant indiquer que l'intrusion date du paléozoïque inférieur.

On a analysé en partie ce complexe pour découvrir les possibilités économiques de la minéralisation, mais les résultats ont été décevants. Il vaudrait peut–être la peine de procéder à un examen plus approfondi.

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Introduction

The Hecla–Kilmer Alkalic Rock Complex straddles the Hecla–Kilmer Townships line south of Mattagami River. The complex is unexposed and lies within the Kapuskasing Subprovince of the Superior Province. The poor access and lack of exposure has inhibited work on the complex. The complex remains poorly known since work on the complex has been limited and the work completed has located little of economic interest.

Acknowledgments

The Ontario Ministry of Natural Resources provided a helicopter to the author in 1978. The author was assisted by Mr. Steve Wilkinson in sampling the core. In 1988, Mr. A. Lisowyk revised the tables of analytical data in the appendix.

Location and Access

The complex (Figure 1) lies on the boundary between Hecla and Kilmer Townships approximately 5 km south of the Mattagami River. A former campsite exists on the east side of Pike Creek which crosses the west side of the complex. Float–equipped aircraft can land on the Mattagami River, however, the former campsite is accessible only by helicopter. Pike Creek, at the time of the author's visit, was too shallow for canoe access. The complex is located 16 km northwest of Coral Rapids which is served by a line of the Canadian National Railway. On the basis of aeromagnetic data (ODM–GSC 1964) (Figure 2) the complex has a surface area of approximately 20 km^2.

Field Methods

The lack of outcrop prevents surface mapping. All lithologic and chemical data must be obtained from drilling. Samples were collected from drill core abandoned in the bush by Ashland Oil and Refining Company in 1969. The numbers on some of the boxes were illegible or barely legible and thus some of the samples discussed may have been assigned to the wrong hole and depth.

Previous Geologic Work

Ashland Oil and Refining Company and Elgin Petroleum Corporation Limited investigated the economic potential of the complex in 1969. There have been no previous published reports on the complex. Bell and Blenkinsop (1980) completed Rb–Sr isotopic studies on the intrusion.

Physiography

The terrain covering the complex is low and wet with negligible relief.

Laboratory Technique

Homogeneous sections of core were selected for thin section examination and those specimens displaying the most homogeneous texture and the least alteration were selected for complete rock analysis.

Nomenclature

Nomenclature used in mapping alkalic rock – carbonatites of Ontario is modified after that of Parsons (1961). The author has used a somewhat different nomen-

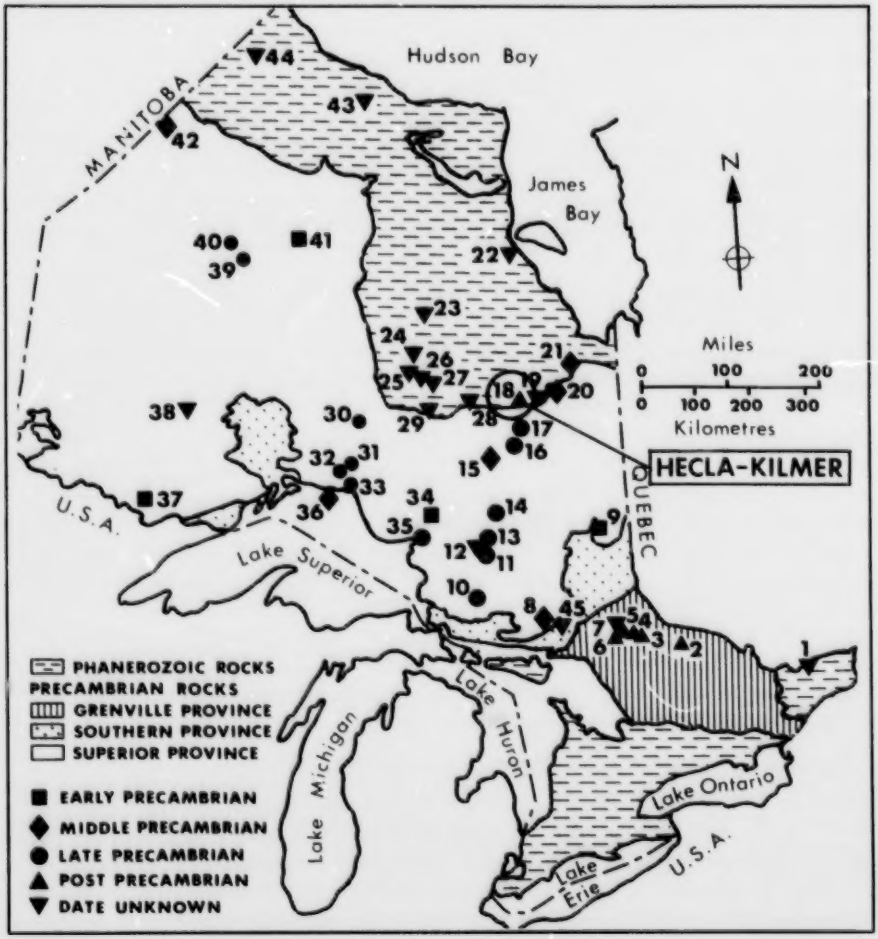

Figure 1. *Key map showing location of carbonatite - alkalic rock complexes in Ontario.*

1. *Eastview*
2. *Brent*
3. *Callander B.*
4. *Manitou Is.*
5. *Burritt Is.*
6. *Iron Is.*
7. *Lavergne*
8. *Spanish R.*
9. *Otto Stock*
10. *Seabrook L.*
11. *Lackner L.*
12. *Borden Tp.*
13. *Nemegosenda L.*
14. *Shenango Tp.*
15. *Cargill Tp.*
16. *Teetzel Tp.*
17. *Clay-Howells*
18. **Hecla-Kilmer**
19. *Valentine Tp.*
20. *Goldray*
21. *Argor*
22. *Lawashi R.*
23. *Poplar R.*
24. *Albany Forks*
25. *L. Drowning R.*
26. *Kingfisher R. West*
27. *Kingfisher R. East*
28. *Martison L.*
29. *Nagagami R.*
30. *Chipman L. (dikes)*
31. *Killala L.*
32. *Prairie L.*
33. *Port Coldwell*
34. *Herman L.*
35. *Firesand R.*
36. *Slate Is.*
37. *Poohbah L.*
38. *Sturgeon Narrows & Squaw L.*
39. *Schryburt L.*
40. *Big Beaver House*
41. *Wapikopa L.*
42. *"Carb" L.*
43. *Gooseberry Br.*
44. *Niskibi L.*
45. *Nemag L. & Lusk L.*

clature in the present report, in conformity with the nomenclature used in describing other alkalic rock – carbonatite complexes in northern Ontario. For the alkalic rocks, the author prefers to use mineralogic, colour, or textural modifiers, which are familiar to all readers, rather than unfamiliar rock names. Alkalic rock nomenclature is cumbersome, due in large part to the profusion of unfamiliar rock names. Consequently, as an aid to the reader, the use of less familiar rock names will be limited. The rock terms retained by the author and the way they are used are given below.

Ijolite. A nepheline–pyroxene rock with a nepheline content between 30 and 70%. Rocks containing more than 70% nepheline are classified as urtite and those with less than 30% as melteigite. Some specimens may contain significant amounts of biotite in place of pyroxene. Potassium feldspar content is 10% or less and those rocks with 10% or less nepheline are classified as pyroxenite.

Malignite. A melanocratic nepheline syenite. In general, nepheline, pyroxene and potassium feldspar occur in roughly equal proportions. The potassium feldspar content must exceed 10% or the rock is classified as belonging to the ijolite suite. Both the nepheline and pyroxene content must exceed 10% or the rock would be classified with the syenites. This rock group is transitional between the ijolites and overlaps the syenitic rock groups.

Sovite. A carbonatite rock composed of 50% or more calcite. Various mineralogic modifiers are used to classify the sovite, for example, apatite–magnetite sovite, olivine–amphibole sovite, etc.

Silicocarbonatite. A carbonate–rich rock containing 50% or more oxide and silicate minerals. Where the silicate or oxide minerals make up more than 90% of the rock, various other rock names are applied; i.e. ijolite, biotite, pyroxenite, etc.

Syenite. This term is restricted to a quartz–free rock consisting primarily of alkali feldspars. Various mafic minerals and nepheline may be present and form a significant component of the rock. The syenites are named on the basis of their mineralogy, i.e., pyroxene–nepheline syenite, biotite–amphibole syenite, etc. The syenites are gradational into malignites.

There is no standard subdivision of the ijolite suite into ijolite, urtite, and melteigite. Bailey (1974) classified urtites as having more than 70% nepheline, however he used the term ijolite to apply only to those rocks containing between 50 and 70% nepheline. The author finds this range to be too restricted for field use and prefers the 30 to 70% range given by Williams *et al.* (1954, p.70).

Malignite from the Poohbah Lake Complex in northwestern Ontario was originally defined by Lawson (1896) as an alkali–rich rock containing pyroxene, and potassium feldspar, with or without nepheline, garnet and amphibole. The author has examined the malignite of this complex in the field and in a large number of thin sections. The malignites are melanocratic and contain pyroxene, nepheline, orthoclase, garnet, and amphibole. The nepheline content of the type location is relatively low compared with the definition given above. For field work and to better emphasize the gradational nature of malignite into ijolites and syenites without the use of cumbersome terminology, a broader usage of the term has been applied by the author. Williams *et al.* (1954, p.65–66)described a number of malignites of varying mineralogy.

The Poohbah Lake type location for malignite was re–investigated by Mitchell and Platt (1978) and malignite was redefined by them as a nepheline syenite containing oikocrystic potassium feldspar. The author considers the defi-

nition of Mitchell and Platt too restrictive. The term malignite is used by the author for a melanocratic nepheline syenite as defined by Sorensen (1974, p.27).

The definitions of sovite and silicocarbonatite are modified from Heinrich (1966, p.12). The author has found Heinrich's subdivision of the carbonate–rich carbonatitic rocks generally suitable for field usage when modified to a two–fold subdivision at about 50% oxide and silicate mineral contents. The two–fold subdivision is more convenient than the four–fold subdivision of Heinrich (1966) because carbonatites show extreme variations in mineral content over distances of less than a few centimetres. It is difficult to rigorously classify such heterogeneous rocks.

General Geology

The Hecla–Kilmer Alkalic Rock Complex lies within the Kapuskasing Subprovince of the Superior Province. Bell and Blenkinsop (1980) using samples collected by the author obtained a scatter of rubidium–strontium isotopic data at about 450 Ma suggesting the complex is early Paleozoic in age. This would be the youngest age so far obtained on an alkalic complex within the region. The complex sits midway between the Middle Precambrian Argor Complex and the Late Precambrian Clay–Howells Complex. Table 1 lists the lithologic units found at the Hecla–Kilmer Alkalic Rock Complex. The lithologies described may not be representative of the complex as a whole, but can be considered as representative of only those phases penetrated by drilling.

The Hecla–Kilmer complex (Figures 2, 3) lies beneath a thick blanket of muskeg, boulders, sand and clay. Portions of the complex lie beneath a thin veneer of dark brown mudstone (drill logs, Assessment Files Research Office, Toronto). On Ashland Oil – Elgin Petroleum's drill logs for inclined holes, the mudstone varies from 0 to 10 m thick. The mudstone was considered to be

TABLE 1. TABLE OF LITHOLOGIC UNITS FOR THE HECLA-KILMER ALKALIC ROCK COMPLEX.

CENOZOIC

QUATERNARY

Recent and Pleistocene

Swamp, stream and glacial deposits.

Unconformity

MESOZOIC

Dike Rocks

Lamprophyre.

Intrusive Contact

PALEOZOIC

DEVONIAN (?)

Sedimentary Rocks

Mudstone.

Unconformity

ORDOVICIAN (?)

HECLA-KILMER ALKALIC ROCK COMPLEX

Syenitic Rocks

Nepheline syenite; amphibole nepheline syenite.

Intrusive Contact

Mafic to Ultramafic Rocks

Olivine essexite; ijolite; pyroxenite; gabbro.

Intrusive Contact

EARLY PRECAMBRIAN (ARCHEAN)

Gneissic Rocks

Devonian in age by those logging the core for the company. Examination of core from the upper surface of the complex indicates that the feldspars of the nepheline syenites are commonly altered to a clay–like mineral possibly due to circulating acid ground water. X–ray diffraction studies of this alteration by W. Hicks (Geoscience Laboratories, Ontario Geological Survey, Toronto) indicate that this clay–like material is hydronephelite after nepheline.

Examination of the drill core with respect to position of the drill holes suggests the presence of a ring complex consisting of a core of mottled red to red–brown, coarse–grained nepheline syenite and a rim of medium–grained olivine essexite. Subordinate ijolite and pyroxenite are also present. The pyroxenite may be a reaction product between the essexite and nepheline syenite. The ijolite is gradational into the olivine essexite, marked by the gradual appearance of olivine and feldspar. Diamond drillhole No. 6 encountered a thick section of lamprophyre consisting of coarse–grained phlogopite up to 4 cm in diameter in an aphanitic groundmass. This mafic rock is likely a dike. Carbonate veinlets were observed, but they appear more typical of carbonate–filled fractures or vein fillings rather than carbonatite. Fluorite was noted at several locations within the

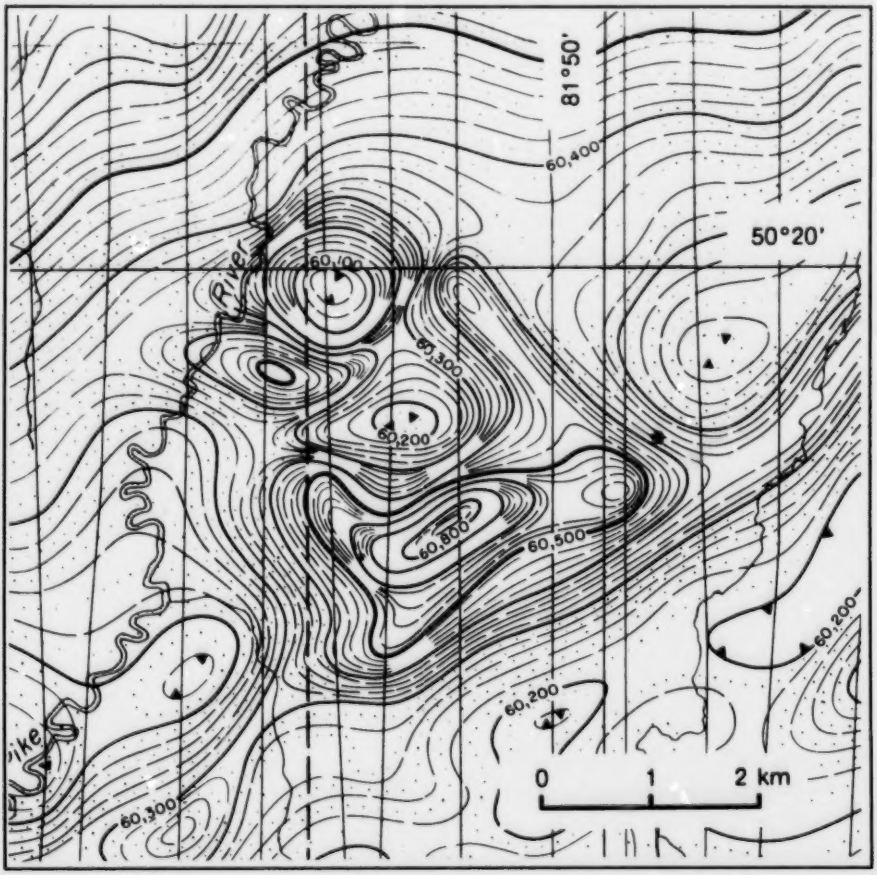

Figure 2. *Aeromagnetic map of the Hecla–Kilmer Alkalic Rock Complex (from Aeromagnetic Map 2307G, ODM–GSC 1964).*

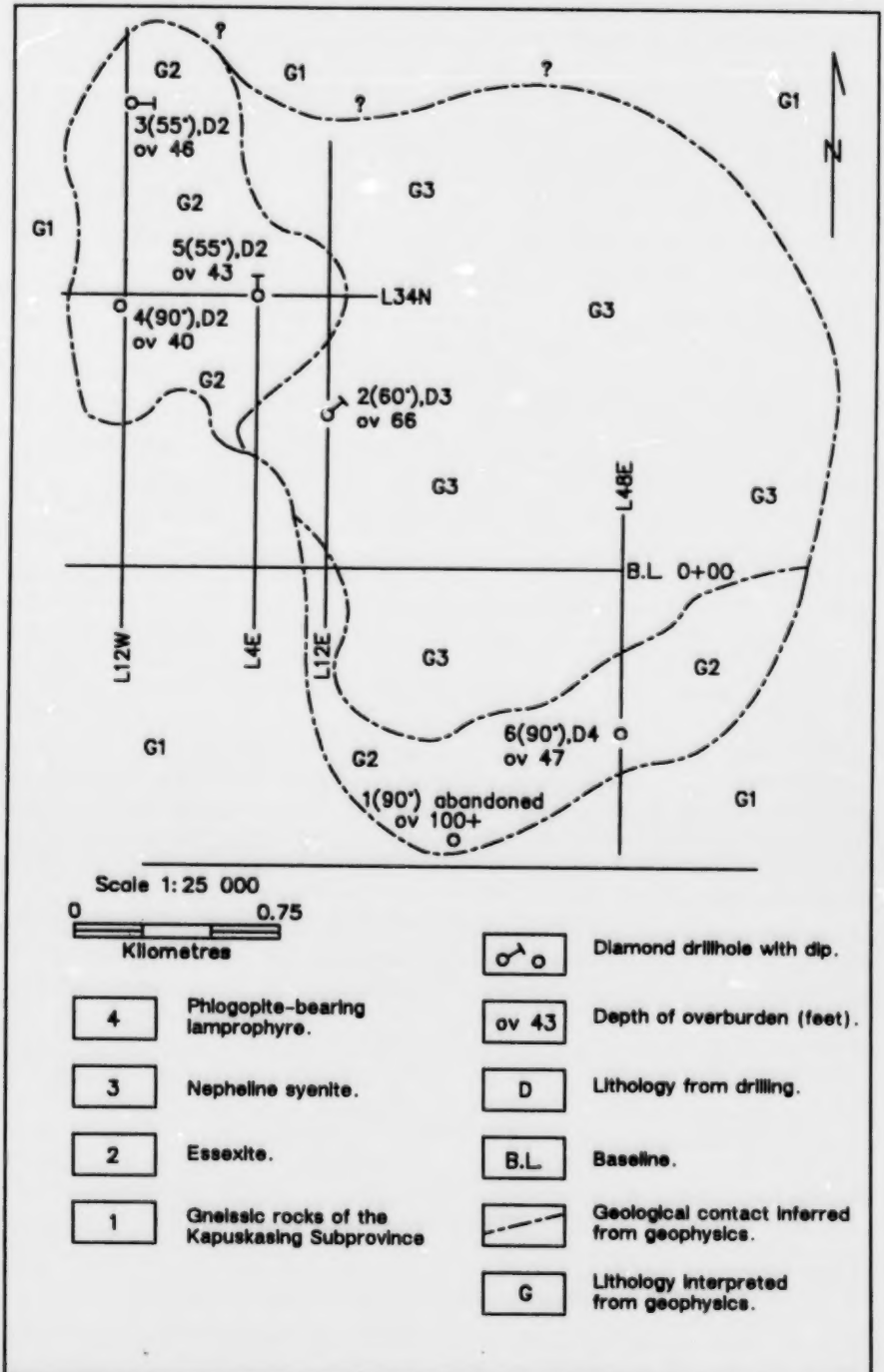

Figure 3. *Geological sketch map of the Hecla-Kilmer Alkalic Rock Complex. Adapted from company plans (Assessment Files Research Office, Ontario Geological Survey, Toronto).*

diamond drill core but it does not occur in major concentrations. No evidence for base metal sulphide or carbonatite–type mineralization was observed.

PALEOZOIC (DEVONIAN - ORDOVICIAN ?)

HECLA-KILMER ALKALIC ROCK COMPLEX

Olivine Essexite

Olivine essexite is one of the dominant rock types encountered in the limited drilling on the body. The rock type appears transitional between ijolite and olivine gabbro and has not been observed by the author in other complexes examined. Essexite is defined as an alkali gabbro primarily composed of plagioclase, hornblende, biotite, titanaugite, with lesser amounts of alkali feldspar and nepheline (AGI 1987). The Hecla–Kilmer essexite differs from true essexite in that it contains olivine and lacks potassium feldspar. The rock is one of the freshest lithologies intersected in holes No. 4 and 5. In hole No. 4 it was logged by the company as "basic breccia" and in hole No. 5 as "malignite". The dominant texture of this rock unit is fine to medium grained, massive, equigranular, hypidiomorphic. Some samples are allotriomorphic, with curved to straight grain boundaries.

In thin section the mode of this rock type is estimated to be 10 to 20% olivine, 0 to 5% amphibole, 30 to 50% clinopyroxene, 5 to 15% plagioclase (An 30–53), 20 to 35% nepheline, trace to 3% apatite, 0 to 5% biotite and 0 to 5% magnetite. The major components would average approximately 15% olivine, 15% plagioclase (An 45), 40% clinopyroxene and 30% nepheline.

Olivine occurs as anhedral round grains in isolation or as aggregates of several grains. Along the edges and curved internal fractures is opaque (magnetite) alteration. Rimming the magnetite is a pale green chlorite. The olivine displays reaction relationships with the other components. These reaction textures appear to be best developed where the olivine lies in contact with nepheline. Iddingsite and fine–grained biotite are rare alteration products of the olivine. Small olivine grains were rarely noted poikilitically enclosed in clinopyroxene.

Amphibole occurs as yellow–brown to red–brown interstitial grains partially enclosing plagioclase, nepheline, magnetite, olivine and clinopyroxene. Amphibole also occurs as irregular and patchy replacements along the corners and rims of clinopyroxene grains.

The clinopyroxene is anhedral to euhedral and forms an interlocking mosaic of grains. The pyroxene is colourless, rarely twinned, rarely zoned, and may display patchy alteration to amphibole along edges and corners. Spotty and irregular amphibole replacement that occurs internal to some grains may, in part, be cleavage controlled. The clinopyroxene was observed to poikilitically contain magnetite and more rarely, irregular plagioclase grains. In one thin section apatite was poikilitically enclosed and in several sections a rare grain of olivine is enclosed. Narrow rims of magnetite followed by biotite may rim the poikilitically enclosed olivine. Rarely, a red–brown biotite alteration accompanies amphibole alteration of the pyroxene. The pyroxene was optically identified as augite.

The plagioclase grains occur as an interlocking, interstitial aggregate of anhedral grains. The plagioclase is fresh with turbid saussuritized rims in contact with the other mineral components which imparts a ragged appearance to the grains. The alteration is most intense where the plagioclase lies adjacent to nepheline.

The nepheline occurs as anhedral to euhedral grains interlocking with, and interstitial to, the clinopyroxene. The mineral was noted to enclose tiny grains of clinopyroxene in one section and to partially enclose plagioclase in a second. The mineral varies from reasonably fresh to totally altered. The alteration occurs along the edges of the grain and as a seriate ragged alteration parallel to the "c" crystallographic axis. The alteration is a very fine–grained fibrous mineral, possibly a zeolite. An apatite grain was noted enclosed in nepheline in one thin section.

Apatite occurs as euhedral prismatic crystals poikilitically enclosed in nepheline, pyroxene, rarely magnetite and olivine. One plagioclase grain was noted to enclose an apatite crystal.

Biotite is red–brown in colour, crudely tabular and mainly occurs interstitially and more rarely as a minor alteration of the clinopyroxene and olivine. The interstitial grains are likely late stage magmatic in origin while most of those associated with pyroxene and olivine result from reaction with late stage magmatic fluids. The tabular grains are interstitial while those replacing or rimming pyroxene and olivine tend to be very fine–grained and somewhat felty or fibrous in appearance.

Ijolite

The term ijolite is restricted to those rocks composed essentially of pyroxene and nepheline. Rocks classified as ijolite were restricted to samples from hole No. 4. The relationship between the olivine essexite and ijolite is unclear but it would appear that they are gradational into each other. The drill logs of Ashland Oil and Refining Company and Elgin Petroleum Corporation Limited classify this section as a basic breccia.

The ijolite is fine to medium grained, massive, equigranular to inequigranular–seriate, hypidiomorphic. A number of samples are allotriomorphic, with curved to straight grain boundaries. In thin section the mode is estimated to be 10 to 15% magnetite, 48 to 70% clinopyroxene, 10 to 40% nepheline, 0 to 20% carbonate and 0 to 5% biotite. The estimated average mode is 12 to 14% magnetite, 50 to 55% pyroxene and 30% nepheline. The more mafic, pyroxene–rich phase (one specimen) could be classified as melteigite.

In thin section the magnetite occurs as anhedral to subhedral grains disseminated throughout the thin section. The magnetite occurs poikilitically enclosed in the pyroxene and minor fine–grained magnetite occurs as a breakdown of the clinopyroxene where it is commonly associated with fine–grained felty to fibrous biotite.

The clinopyroxene is anhedral to subhedral, colourless, and commonly poikilitically encloses magnetite grains. Rarely the pyroxene may enclose nepheline (generally completely altered) and display traces of very fine–grained biotite alteration along grain edges and corners. More rarely, traces of biotite may occur along internal fractures within the grains and in one section carbonate occurs along internal fractures.

Nepheline, recognized by its crystal form and type of minerals to which it has altered, occurs as anhedral to subhedral grains interstitial to the pyroxene and rarely as round to subrounded blebs enclosed in pyroxene. The nepheline is totally altered to a very fine–grained fibrous mat possibly of zeolite composition.

One sample contains appreciable carbonate. The carbonate is interstitial and anhedral.

Biotite is minor within this lithology and resulted from the breakdown of pyroxene. The biotite is green–brown in colour, very fine–grained and formed along the edges and more rarely along internal fractures within the pyroxene.

Pyroxenite

Rocks classified as pyroxenite were encountered in hole No. 6 where they were logged as pyroxenite by Ashland Oil – Elgin Petroleum. With the exception of one sample, the rocks of this group (total 4 samples) were so badly altered as to inhibit petrographic study.

The one fresh pyroxenite rock in thin section is fine to medium grained, massive, equigranular to inequigranular–seriate, allotriomorphic, with straight to curved grain boundaries.

In thin section, the one sample of fresh pyroxenite is estimated to contain 5% apatite, 65% clinopyroxene, 15% amphibole and 15% magnetite. The accompanying petrographic observations are based on the one relatively fresh sample.

The apatite occurs as euhedral prismatic grains poikilitically enclosed in magnetite, pyroxene and amphibole. The larger grains are fractured.

The magnetite is anhedral to subhedral, disseminated, and commonly rimmed with very fine–grained biotite reaction rims.

Clinopyroxene occurs as colourless, anhedral to subhedral interlocking grains. Rare twinning is present. The mineral is extensively fractured and veined with very fine–grained biotite alteration with possibly some carbonate.

The amphibole is pleochroic in yellow–brown and occurs in two habits: (1) as grains interstitial to the pyroxene and (2) as scattered irregular patchy replacements on the edges and corners of the pyroxene grains.

One thin section contains an estimated 25% phlogopite which is likely a breakdown product of the pyroxene. Bending of the (001) cleavage on the larger grains was noted.

A very fine–grained brown alteration may comprise up to 70% of some samples. This alteration appears to be a mixture in widely varying proportions of very fine–grained biotite–phlogopite, dusty fine–grained magnetite, prismatic colourless amphibole and carbonate. This alteration is considered by the author to be largely the result of pyroxene breakdown.

Plagioclase (An 34–36?) in a visually estimated amount of 15% was noted in one sample. The plagioclase is fine grained, ragged, turbid, flecked with sericite(?), and forms interlocking aggregates with serrate grain boundaries. The albite twinning is patchy and discontinuous across individual grains.

Nepheline Syenite, Amphibole Nepheline Syenite

Nepheline syenite and amphibole nepheline syenite, in thin section, are medium to coarse grained, massive, inequigranular–seriate, allotriomorphic with curved to straight grain boundaries. Rarely the texture is hypidiomorphic or approaching hypidiomorphic.

In thin section the mode is estimated to be 0 to 5% biotite, 0 to 10% amphibole, 2 to 40% nepheline, 50 to 60% perthite, 0 to 5% opaques, 0 to 10% carbonate and traces of apatite. A brown alteration, most likely after amphibole may compose up to 20% of some samples.

The biotite occurs as a brown, very fine–grained felty to fibrous interlocking aggregate. The biotite is most likely an alteration after amphibole. Locally it is associated with fine–grained carbonate.

The amphibole is anhedral, interstitial and green–brown in colour. In one case the amphibole had broken down into acicular colourless amphibole, possibly actinolite. The amphibole is generally altered, and fresh amphibole is rare. The turbid fine–grained brown alteration patches found in most samples in quantities up to an estimated 20% are interpreted by the author to be a breakdown product of former amphibole. Optically this breakdown product appears to be a fine–grained mixture of opaques, biotite, carbonate and prismatic amphibole. In one sample the green–brown amphibole has pale green–brown to colourless rims implying compositional variation.

The nepheline occurs as anhedral to subhedral grains interstitial to the perthite and as round blebs completely enclosed within perthite. While relicts of fresh nepheline are present, most of the nepheline is altered to a very fine–grained fibrous mat of possible zeolite. Carbonate and sericite may also be part of this breakdown assemblage. In the original sampling a buff clay–like mineral was encountered in upper sections of core samples from hole No. 2. An X–ray diffraction pattern of this material was identified by W. Hicks (Geoscience Laboratories, Ontario Geological Survey, Toronto) as hydronephelite, presumably after nepheline. Within the other sections of the core, a coarse–grained dull red mineral interpreted as nepheline is abundant and closely associated with red– brown perthitic potassium feldspar. An X–ray diffraction pattern of this red mineral was interpreted by W. Hicks as analcite. Analcite, occurring interstitially like nepheline, was observed optically in two specimens but in most cases the feldspathoid present was nepheline. Since alteration is extensive the relative proportions of nepheline and analcite are impossible to estimate.

Perthite is the only feldspar present within this rock suite. The perthite displays a stringy texture, occasional Carlsbad twinning, and may contain irregular patches with vestiges of albite twinning. The perthite may contain small flecks of saussurite. Rarely, narrow mantles of albite feldspar occur on some grains and occasionally a relatively small grain of albite occurs intergranular to the perthite grains. Some grains of perthite are turbid or clouded throughout. Perhaps a very fine–grained clay mineral disseminated in some of the feldspar imparts a turbidity to the feldspar. The perthite encloses round blebs of nepheline in a number of samples.

The opaques are fine grained and appear to be largely the breakdown products of former amphibole. Iron oxide and red–brown limonite appear to be the opaque components.

The minor quantity of carbonate present occurs in association with the zeolitic alteration of the nepheline and breakdown of the former amphibole. Minor carbonate occurs with quartz, filling a hairline fracture in one sample.

Traces of apatite as small grains occur within the breakdown products of the amphibole and were likely originally poikilitically enclosed within the amphibole.

Quartz occurs as a filling of a hairline fracture in association with carbonate.

Purple fluorite occurs interstitially in trace amounts within the syenites. Within holes No. 2 and 3 narrow zones on the order of 0.3 m wide and possibly occupying zones of brecciation are fluorite–rich. The fluorite occurs in quantities estimated to exceed 60% and it is associated with carbonate and pyrite. The identity of the fluorite has been confirmed by X–ray diffraction studies by W. Hicks. The fluorite from hole No. 3 was analysed spectrographically (Table 2) by the Geoscience Laboratories (Ontario Geological Survey, Toronto). The enrichment in rare earths implies alkalic rock–carbonatite affinity. The fluorite, carbon-

TABLE 2. SPECTROGRAPHIC ANALYSIS OF FLUORITE FROM HECLA-KILMER ALKALIC ROCK COMPLEX.

	I	II
Ce	ND (<0.1%)	TL (~0.1%)
La	T (>0.01%)	TL (0.1-0.3%)
Nd	ND (<0.01%)	TL (~0.1%)
Sc	ND (<0.01%)	ND (<0.01%)
Y	T (<0.01%)	T (>0.03%)
Yb	ND (<0.005%)	ND (<0.005%)
Eu	ND (<0.01%)	T (>0.01%)

Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.
I - Sample HK3 580-605, whole rock.
II - Sample HK3 580-605, fluorite concentrate.

Abbreviations:
ND = Not detected
T = Trace
TL = Trace to low

ate and pyrite zones, may represent the accumulation of late stage fluorine-rich interstitial fluids in fracture zones within a consolidated alkalic intrusion.

MESOZOIC

DIKE ROCKS

Within the drill core two rock types are interpreted as possibly being dikes. The relationship of the dikes to the complex is unknown due to the lack of data. Age relationships of the gabbro dike are unknown other than that it is younger than the Hecla-Kilmer complex, dated at approximately 450 Ma. The lamprophyre dike cuts the Hecla-Kilmer complex and is younger than its host. Lumbers (1978) classified kimberlitic rocks of the general region as Mesozoic, falling into the age range of 90 to 150 Ma. The lamprophyre is tentatively placed into this age group.

Gabbro

Within samples collected from hole No. 6, one specimen appears to be an altered gabbro or diabase dike or perhaps even a xenolithic block within the Hecla-Kilmer complex. The texture is different from that of the olivine essexite and ijolite. The rock is tentatively classified as a dike rock, however the drill core for this portion of hole No. 6 has been described as pyroxenite by the company. In thin section the rock is fine grained, massive, inequigranular-seriate, hypidiomorphic. The mode is estimated as clinopyroxene 30%, biotite 30%, plagioclase 30% and carbonate 10%.

The clinopyroxene is colourless, has a weak concentric zoning, and displays ragged edges caused by alteration of the edges to fine-grained biotite.

The biotite is a pale yellow-brown, very ragged, commonly fine grained, and likely occurs dominantly as an alteration product of the pyroxene.

The plagioclase forms ragged grains with clear cores and ragged saussuritized rims. The plagioclase occurs in tabular, interlocking aggregates.

The carbonate is very fine grained, interstitial and disseminated throughout.

Lamprophyre

Within hole No. 6, the bottom 36.9 m consists of a phlogopite–porphyritic lamprophyre. The rock contains euhedral grains of phlogopite up to 4 cm in diameter set in a matrix of fine–grained phlogopite. In thin section, the rock is fine to coarse grained, massive, inequigranular–porphyritic–seriate, hypidiomorphic. Modally the rock consists of an estimated 5% phlogopite phenocrysts, 10 to 15% opaques, 20 to 30% carbonate and 55 to 60% fine–grained phlogopite.

The phenocrysts are euhedral to subhedral, and display kinking and bending of the (001) cleavage. The large crystals are set in a fine–grained matrix of similar material. The fine–grained mica forms a mat of interlocking grains.

The carbonate occurs as fine–grained, interstitial grains, as tiny hairline streaks, and as round blebs of anhedral grains much coarser than the interstitial carbonate.

The opaque is likely magnetite and occurs as anhedral, fine–grained, disseminated grains. Minor talc may be present.

This dike cuts the Hecla–Kilmer Alkalic Rock Complex which on the basis of Rb–Sr studies is probably early Paleozoic in age (Bell and Blenkinsop 1980). The presence of this dike indicates a later period of magmatic activity at the north end of the Kapuskasing Subprovince.

PETROLOGY

The sample suite from the Hecla–Kilmer Alkalic Rock Complex is too limited to define melt trends. It is likely that some of the units may not be simple melt equivalents but were emplaced as solid–liquid mixtures. An AFM diagram (Figure 4) of the chemical data (*see* Appendix A) indicate that the rock types plot into distinct groups and do not define continuous trends. It is expected that the petrogenesis of these rocks cannot be interpreted on the basis of such simple diagrams. One or more petrologic processes have undoubtedly produced this rock suite.

Normative compositions (Appendix A, Table A–4) were calculated by the methods outlined by Irvine and Baragar (1971) and statistical compositions (Appendix A, Table A–5) of each map unit were calculated by the procedures outlined by Nie (1975).

METAMORPHISM

The textures observed within the Hecla–Kilmer samples are primary and show a lack of metamorphic overprint. This lack of metamorphism is considered by the author to be typical of alkalic rock complexes since Early Precambrian time. The rocks are extensively altered. The magnetite–chlorite rims on the olivine grains are considered by the author to have formed by reaction of the olivine with late stage fluids within the crystallizing alkalic magma. The extensive alteration of the amphibole within the nepheline syenite and the extensive alteration of the nepheline in all rock types are also considered to be the result of reaction with late stage magmatic fluids. The often turbid or clouded appearance of the perthite is also likely a product of these fluids. These alterations are considered to be a deuteric or autometasomatic feature and not indicative of an independent metasomatic–metamorphic event.

While the composition of these fluids is unknown and cannot be speculated on, the minerals formed, replaced, and occurring as fracture fillings, suggest that

these late stage fluids contained water, carbon dioxide, fluorine and possibly some sulphur.

STRUCTURAL GEOLOGY

The Hecla–Kilmer complex lies within the Kapuskasing Subprovince which contains many carbonatite–alkalic complexes. These complexes are dominantly of Late Precambrian age (Gittins *et al.* 1967) but the Argor and Goldray carbonatites located northeast of Hecla–Kilmer are Middle Precambrian in age. Preliminary rubidium–strontium isotope data by Bell and Blenkinsop (1980) suggests the Hecla–Kilmer complex is early Paleozoic in age, perhaps around 450 Ma (Ordovician).

The complex lies at the northern end of the Kapuskasing Subprovince which is characterized geophysically by a northeast–trending zone of gravity highs and linear aeromagnetic trends (Innes 1960; ODM–GSC 1970). This anomalous gravity zone has been interpreted to be due to an upwarp in the Conrad discontinuity caused by major regional faulting and the formation of a complex horst structure (Wilson and Brisbin 1965; Bennett *et al.* 1967). This prominent regional structure extends southwest from Hudson Bay and becomes broader and more ill–defined as it approaches and merges with Lake Superior basin.

The Hecla–Kilmer Alkalic Rock Complex is one of many emplaced within the Kapuskasing Subprovince (Satterly 1970; Ayres *et al.* 1970). The presence of Middle Precambrian, Late Precambrian and possibly early Paleozoic alkalic rock – carbonatite complexes in the same region of the Kapuskasing structure implies at least three periods of tectonic activity and alkalic rock – carbonatite magmatism.

More recently Percival and Card (1983) have interpreted the Kapuskasing Subprovince (or Kapuskasing Structural Zone) as an oblique section through 20

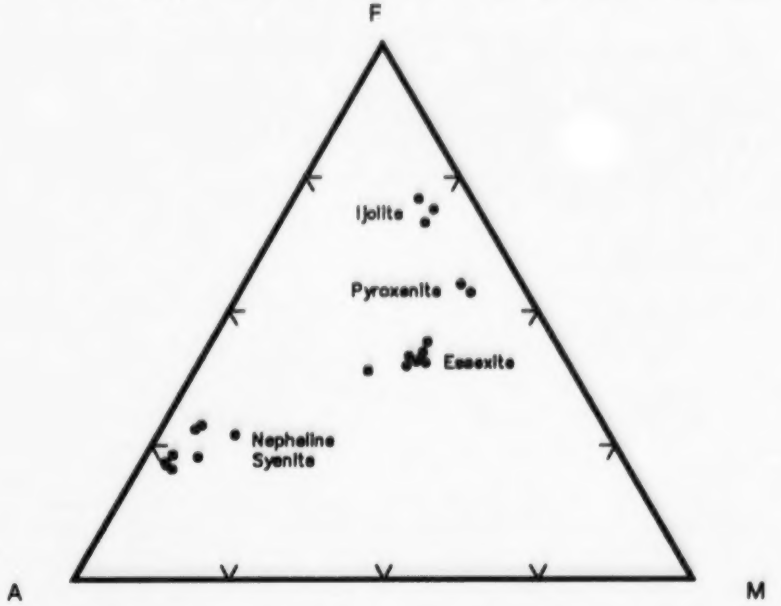

Figure 4. *AFM plots of samples from the Hecla-Kilmer Alkalic Rock Complex. A = Na_2O + K_2O; F = FeO (total); M = MgO.*

km of Archean crust. In the eastern part of the zone, the crust has been uplifted along a northwest–dipping thrust fault which places high–grade rocks adjacent to low–grade rocks to the east. To the west, the high–grade rocks grade into low–grade rocks over a distance greater than 100 km (Percival and Card 1983).

The lack of outcrop prevents any interpretation as to possible internal structures. On a map of a magnetometer survey, submitted by Ashland Oil and Refining Company and Elgin Petroleum Corporation Limited for assessment work credit, R.D. Bradshaw (1969) has interpreted the presence of a number of shear/fault zones with northwest and northeast trend.

GEOPHYSICS

The area of the Hecla–Kilmer Alkalic Rock Complex has been covered by an airborne magnetometer survey (ODM–GSC 1964) (see Figure 2) at a scale of 1 inch to 1 mile. This map shows a crudely circular aeromagnetic anomaly over the complex. The southeast flank is relatively linear being truncated by a northeast–striking aeromagnetic trend. The aeromagnetic anomaly has a diameter of approximately 5 km and a magnetic relief of approximately 600 gammas absolute total field intensity above background.

Ground magnetic surveys completed by Ashland Oil and Refining Company and Elgin Petroleum Corporation Limited indicate a circular anomaly with a complex ring of magnetic highs and lows enclosing a central area of relatively flat magnetic relief. The highly erratic magnetic pattern of the rim has a maximum relief on the order of approximately 500 gammas and is likely due to widely varying magnetite content within the olivine essexite, ijolite and pyroxenite. The relief of the core is on the order of 150 to 900 gammas and is likely underlain by nepheline syenite.

The company completed an electromagnetic survey identifying 7 conductive zones. The zones were interpreted by the company as shear zones or faults (File 63–2547, Assessment Files Research Office, Ontario Geological Survey, Toronto).

RECOMMENDATIONS FOR FUTURE STUDY

The lack of outcrop prevents any extensive study of this complex. The existing samples warrant additional detailed optical and microprobe study. If additional drilling is completed on this body, additional study is warranted to better classify and define the rock types and their relationships. A precise isotopic age for this complex is highly desirable to understand the history of alkalic rock magmatism in the Kapuskasing Subprovince.

Economic Geology

The Hecla–Kilmer complex is an alkalic rock complex and not a carbonatite. The moderately high rare earth content of the fluorite implies a close relationship to the alkalic rock – carbonatite suite. No sulphide mineralization was observed within any of the rock units, the nepheline is too altered to be of economic interest, and the fluorite is too scarce and contaminated with carbonate and pyrite to be of economic interest. At present the complex is not known to contain a mineral phase of potential economic interest.

PROPERTY DESCRIPTION

ASHLAND OIL AND REFINING COMPANY — ELGIN PETROLEUM CORPORATION LIMITED [1969]

In 1969 the Ashland Oil and Refining Company and Elgin Petroleum Corporation Limited completed an exploration program over 63 claims known as the "George–Draper–Besetts property" covering the Hecla–Kilmer Alkalic Rock Complex. The companies completed a ground magnetometer survey, an electromagnetic survey and a geochemical survey. Six diamond drill holes (5 to bedrock) were completed totalling 866 m (2886 feet) (Assessment Files Research Office, Ontario Geological Survey, Toronto). This program was unsuccessful in locating mineralization of interest and work was discontinued.

The geochemical survey determined that most of the property covering the Hecla–Kilmer Alkalic Rock Complex is overlain by more than 1.5 m of muskeg with portions in the northeast consisting of clay overlain by 0.3 to 1.2 m of muskeg (Bradshaw 1969). The company analyzed for copper, zinc and uranium. Four samples were reported to contain anomalous zinc, one sample anomalous copper and no samples contained anomalous uranium (Bradshaw 1969). The company concluded that the results were not subject to reasonable interpretation (Bradshaw 1969).

RECOMMENDATIONS FOR PROSPECTORS

The nepheline has been altered to a bright red, very fine–grained mineral throughout. The alteration of the nepheline precludes the possibility that the nepheline could have economic importance.

Fluorite occurs in too limited quantities to be of economic interest. Sulphide mineralization of any significance has not been observed within any of the lithologic units. Minor pyrite occurs with the fluorite but is of no economic interest. Considering the fact that the complex may approach 4.8 km in diameter and has been penetrated by only 5 diamond drill holes, much remains unknown. While initial results are not encouraging the existing data are too limited to preclude further investigation of the intrusion.

Considering the coarse–grained nature of the nepheline syenite, which may make it more amenable to milling, the delineation of zones of unaltered nepheline syenite might be possible within the core area. Pyrochlore–bearing syenite aplite dikes occur within the Port Coldwell alkalic rocks and their uranium–niobium content has prompted several exploration programs. Perhaps similar dikes exist within the Hecla–Kilmer complex.

While a ground magnetic survey will help outline the complex and in conjunction with limited subsurface data permit the extrapolation of various lithologic units, neither ground magnetic nor electromagnetic surveys are likely to outline potentially economic zones of nepheline syenite or pyrochlore–bearing dikes. The overlying muskeg and thin veneer of Paleozoic rocks (mudstone) will shield any radioactive zones and prevent their location. Presently used geochemical techniques are not likely to be of value within muskeg. Diamond drilling is the best way to prospect this body.

Appendix A — Petrographic Descriptions, Chemical Analyses, Normative Compositions, and Statistical Compositions of Lithologic Units of the Hecla–Kilmer Alkalic Rock Complex.

TABLE A-1. PETROGRAPHIC DESCRIPTIONS OF WHOLE-ROCK SAMPLES* FROM THE HECLA-KILMER ALKALIC ROCK COMPLEX.

Reference No. 1293
Sample No. HK-2A

Nepheline syenite.

Medium to coarse grained massive, equigranular, allotriomorphic, with straight and curved grain boundaries. Nepheline forms anhedral grains interstitial to perthite and is completely altered to a fibrous zeolite(?). Perthite is stringy-textured, turbid, Carlsbad twinned, anhedral, and flecked with saussurite. The mafic mineral is completely altered to very fine-grained biotite, magnetite, carbonate and fibrous amphibole. Biotite forms anhedral to euhedral brown grains, generally associated with carbonate. Carbonate occurs as large anhedral grains forming an interstitial mosaic.

Reference No. 1294
Sample No. HK-2B

Nepheline syenite.

Medium to coarse grained, massive, inequigranular-seriate, allotriomorphic, with curved to straight grain boundaries. Perthite is stringy, and its edges may have traces of albite. Carlsbad twinning is present. Perthite may contain irregular blebs of totally altered nepheline, is flecked with saussurite, and is somewhat turbid. Minor euhedral, prismatic, apatite remains in mafic mineral decomposition products. Nepheline occurs as irregular anhedral grains interlocking with perthite, and also totally altered to very fine-grained carbonate.

Reference No. 1295
Sample No. HK2 330-355B

Amphibole nepheline syenite.

Medium to coarse grained, massive, inequigranular-seriate, allotriomorphic, with curved to straight grain boundaries. Fine-grained, prismatic, nearly colourless amphibole occurs as part of breakdown of former amphibole. Biotite is a fine-grained brown breakdown product of a former amphibole. Opaques are irregular in shape, possibly limonite after former amphibole in association with prismatic amphibole and biotite. Carbonate is interstitial, replacing former nepheline and amphibole. Nepheline is totally altered to carbonate and zeolites. Perthite forms anhedral interlocking grains with a stringy texture. Carslbad twinning is present. Perthite is flecked with sericite and carbonate. Minor interstitial albite (An-8) is present; grains with albite twinning have spotty diffuse cores.

Reference No. 1296
Sample No. HK2 330-355A

Amphibole nepheline syenite.

Medium to coarse grained, massive, inequigranular-seriate, allotriomorphic, with straight to curved boundaries. Biotite is present as fine-grained equigranular, irregular, interlocking grains, in part, after amphibole. Amphibole is anhedral equigranular and somewhat prismatic. Amphibole is colourless with irregular turbidity; larger grains are green with colourless rims. Nepheline is commonly altered to zeolite and carbonate with irregular fresh cores. The nepheline occurs as interstitial grains with perthitic feldspar. Nepheline also occurs as rounded blebs within the perthite. Opaques occur as irregular blebs and may result from the breakdown of the green-brown

**All samples were taken from drill core of Ashland Oil and Refining Co. and Elgin Petroleum Corporation Ltd. The locations of the drillholes are plotted on Figure 3. The sample number indicates the hole number and the depth in feet of the core sample (where known).*

amphibole to biotite and colourless amphibole. Carbonate occurs along fractures with zeolites and as a fine-grained mosaic with zeolites after nepheline. Apatite occurs in trace amounts as poikilitic inclusions within altering amphibole. Perthite forms irregular interlocking grains. The perthite is of the stringy type and displays Carlsbad twinning. Albite(?) forms distinct grains between perthite grains and forms clear rims on perthite grains.

Reference No. 1297
Sample No. HK3 280-305

Pyroxenite.

Fine to medium grained, inequigranular-seriate, allotriomorphic, with straight to curved grain boundaries. Due to extensive alteration the texture is somewhat problematical. Pale brown, anhedral amphibole occurs in very minor amounts. Apatite is irregular, anhedral to euhedral, and poikilitic in pyroxene. Prismatic, colourless clinopyroxene forms interlocking grains which are rarely twinned; edges and abundant fractures are altered to amphibole. Minor euhedral brown biotite is present. Opaques form irregular, anhedral grains, round to irregular in form and generally fine grained. Over half of the thin section consists of very fine-grained, interlocking, prismatic pale brown to colourless amphibole. Amphibole is likely the result of pyroxene breakdown.

Reference No. 1298
Sample No. HK3 430-455A

Nepheline syenite.

Coarse grained, massive, equigranular, allotriomorphic, with curved to straight grain boundaries. The rock has hairline fractures containing anhedral grains of carbonate and possibly very fine-grained zeolite along the walls of fractures. Nepheline is present as irregular relicts in a mass of very fine-grained alteration, possibly zeolite and sericite. Perthite is a string perthite flecked with sericite and carbonate; it may enclose rounded altered blebs of nepheline. Rarely grains are mantled with clear albitic feldspar.

Reference No. 1299
Sample No. HK3 430-455B

Nepheline syenite.

Coarse grained, massive, equigranular, allotriomorphic, with straight to curved grain boundaries. Mafic minerals are altered to a very fine-grained mixture of opaques, biotite and prismatic amphibole. Nepheline is anhedral and completely altered to zeolite and possibly some sericite. Perthite is anhedral, stringy, Carlsbad twinned and extensively flecked with carbonate. Some carbonate occurs within hairline fractures in perthite grains.

Reference No. 1300
Sample No. HK704 405-430A

Ijolite.

Fine grained, equigranular, massive, hypidiomorphic, with curved to straight grain boundaries. Nepheline forms rounded to subrounded, anhedral to subhedral, blocky grains totally altered to fibrous zeolite interlocking with and enclosed within clinopyroxene. Clinopyroxene is anhedral to subhedral, clear, and fresh-looking.

Reference No. 1301
Sample No. HK704 155-180A

Ijolite.

Medium grained equigranular, massive, hypidiomorphic, with straight to curved grain boundaries. Opaques are anhedral to subhedral, poikilitic in clinopyroxene. Nepheline is interstitial to pyroxene and totally altered to fine-grained fibrous zeolite. Nepheline also occurs as rounded to subrounded blebs completely enclosed in clinopyroxene. Clinopyroxene is anhedral to subhedral, colourless, fresh, and encloses opaques and altered nepheline.

Reference No. 1302
Sample No. HK704 405-430B

Ijolite.

Fine to medium grained, equigranular, allotriomorphic, with curved to straight grain boundaries. Magnetite forms anhedral disseminated grains, locally poikilitic in clinopyroxene. Fine-grained dusty magnetite occurs along edges and within fractures of clinopyroxene in close association with fine-grained green-brown biotite. Biotite occurs along grain margins and in fractures within grains. Both magnetite and biotite are breakdown products of pyroxene. Nepheline

is totally altered to a fibrous matted mass of zeolite; it occurs interstitial to, and as rounded blocky blebs within, the pyroxene. Clinopyroxene is anhedral tc subhedral and colourless. Biotite and magnetite alteration is present along margins and internal fractures. Clinopyroxene interlocks with and may enclose nepheline.

Reference No. 1303
Sample No. HK704 455-480

Olivine essexite.

Fine to medium grained, massive, equigranular, hypidiomorphic. Clinopyroxene is anhedral to sharply euhedral; zoning is well developed. It contains poikilitic apatite and magnetite. Pyroxene is altered to amphibole along irregular cleavage-controlled fractures. Plagioclase (An 30-53?) forms tabular interlocking crystals, which are interstitial, highly turbid and saussuritized along margins next to nepheline. Nepheline is anhedral and interstitial. Rarely some relicts of nepheline are fresh; most are altered to a very fine-grained fibrous zeolite. Anhedral magnetite is poikilitic in pyroxene and rims olivine. Amphibole is yellow-brown, anhedral, interstitial, and may mantle clinopyroxene in isolated spots. Apatite is anhedral, prismatic, poikilitic in pyroxene. Olivine is anhedral, rimmed with magnetite and with magnetite along curved fractures. Minor biotite rims magnetite and traces of chlorite are present.

Reference No. 1304
Sample No. HK704 455-480A

Olivine-bearing essexite.

Fine to medium grained massive, equigranular, allotriomorphic, with curved to straight grain boundaries. Olivine forms anhedral grains in aggregates altering to red-brown iddingsite, green tinted chlorite and more rarely biotite. Fine-grained magnetite rims olivine and occupy fractures within the olivine. Apatite occurs as prismatic euhdral grains poikilitic in pyroxene, nepheline and rarely olivine. Clinopyroxene is colourless, twinned, and flecked with fine-grained carbonate (?). Plagioclase (An-44) forms tabular, generally fresh grains interlocking with and interstitial to pyroxene. Nepheline is rarely fresh and is commonly altered to a fibrous matted mass of zeolite material. Nepheline is interstitial to pyroxene and plagioclase. Opaques are very fine grained, disseminated and poikilitic in pyroxene. Amphibole is minor, and occurs as pleochroic yellow-brown anhedral grains in part mantling and replacing edges of pyroxene. Amphibole is in part interstitial.

Reference No. 1305
Sample No. Hk5 217-242

Olivine essexite.

Fine to medium grained, equigranular, massive, hypidiomorphic. Apatite forms euhedral, prismatic crystals poikilitic in nepheline, pyroxene and magnetite. Magnetite is anhedral, disseminated, rimmed with chlorite, and poikilitic in pyroxene. Olivine is anhedral, rimmed with magnetite along margins and curved cracks. Chlorite rims magnetite. Nepheline is anhedral to subhedral, interlocking with clinopyroxene, and generally fresh with incipient alteration along edges. Clinopyroxene is anhedral to euhedral, colourless, and shows incipient alteration to amphibole along irregular fractures. The pyroxene poikilitically encloses tiny plagioclase grains and rarely may contain olivine. Magnetite is poikilitic and displays narrow rims of chlorite and biotite(?). Plagioclase (An 41-48) forms tabular interlocking grains interstitial to pyroxene; grains are generally fresh with turbid ragged saussuritized edges. Nepheline is generally fresh, forming anhedral to subhedral interlocking grains, with incipient alteration along edges. An irregular, almost amoeboid, intergrowth of plagioclase and pyroxene implies simultaneous crystallization.

Reference No. 1306
Sample No. HK5 217-242A

Olivine-bearing essexite.

Fine to medium grained, massive, allotriomorphic, with curved to straight grain boundaries. Olivine forms anhedral grains rimmed with magnetite which in turn may be rimmed with chlorite. Curved fractures are filled with magnetite. Amphibole is red-brown and occurs as isolated patches on corners and edges of pyroxene grains. Some grains appear interstitial. Clinopyroxene is colourless, anhedral to subhedral, and partially encloses plagioclase and nepheline, and may be spotted with fine-grained, disseminated magnetite. The magnetite grains occur with amphibole and biotite alteration of pyroxene. Apatite is euhedral, prismatic, and poikilitic in pyroxene. Nepheline forms fresh relicts with ragged borders altered to fibrous zeolite.

Reference No. 1307
Sample No. HK5 217-242B

Olivine-bearing essexite.

Fine to medium grained, massive, equigranular, allotriomorphic, with straight to curved grain boundaries. Nepheline is present in trace amounts as fresh material. Most is altered to a fine-grained turbid mass interstitial to pyroxene. Red-brown biotite occurs in association with magnetite after olivine, and as irregular ragged replacement of pyroxene. There are rare isolated interstitial grains of red-brown biotite. Magnetite is anhedral, in part after olivine, in part poikilitic in pyroxene. Grains within pyroxene are rimmed with chlorite and biotite. Apatite is euhedral, prismatic, poikilitic in pyroxene and plagioclase. Olivine forms anhedral grains rimmed with magnetite and then chlorite. Reaction rims are very well developed. Plagioclase (An 4-44) forms clear tabular interlocking crystals, interstitial to pyroxene. The edges of some crystals are ragged and show turbid fresh alteration. Clinopyroxene forms colourless, anhedral to subhedral grains in part altering to red-brown biotite. Minor pleochroic yellow-brown amphibole is interstitial to pyroxene and in part replaces pyroxene in a ragged fashion.

Reference No. 1308
Sample No. HK5 267-292A

Olivine essexite.

Fine to medium grained, equigranular, hypidiomorphic. Biotite occurs in minor quantities; it is euhedral, red-brown, in part interstitial, in part after pyroxene. Olivine is anhedral, rimmed with magnetite, and magnetite occurs along fractures. Chlorite rims magnetite. Traces of iddingsite were noted along some fractures. Nepheline forms anhedral to euhedral crystals, totally altered. Nepheline generally occurs as clusters of grains. It is altered to very fine-grained, fibrous zeolite(?). Amphibole is anhedral, yellow- to red-brown, interstitial, encloses plagioclase, and nepheline; it may occur as spotty alteration on pyroxene. Plagioclase (An 35-44) forms tabular interlocking grains interstitial to pyroxene. Clinopyroxene is anhedral to euhedral, colourless with incipient alteration to amphibole along irregular cracks. Clinopyroxene contains occasional grains of olivine, apatite, and magnetite. Pyroxene may be concentrically zoned and rare plagioclase inclusion is present. Apatite is euhedral, prismatic, and poikilitic in pyroxene. Magnetite is anhedral and disseminated. It occurs as an alteration of olivine and as small poikilitic grains in pyroxene.

Reference No. 1309
Sample No. HK5 267-292B

Olivine essexite.

Fine to medium grained, massive, equigranular hypidiomorphic. Magnetite is anhedral, poikilitic in pyroxene and occurs as a result of olivine breakdown. Clinopyroxene is anhedral to euhedral, colourless, and may contain poikilitic magnetite and irregular plagioclase grains. It shows incipient alteration to amphibole marginal to magnetite inclusions, and along irregular fractures that are cleavage controlled. Nepheline forms anhedral to euhedral grains, dominantly altered to a fibrous zeolite(?). Nepheline occurs in aggregates of grains and may partially enclose plagioclase. Amphibole is yellow to red-brown in colour, interstitial and locally occurs as irregular replacements of the margins of pyroxene grains. Plagioclase (An 30-44) forms interstitial tabular aggregates. Incipient alteration along margins of grains gives a ragged appearance particularly in the presence of nepheline. Minor biotite is yellow-brown, anhedral, irregular and interstitial. Olivine is anhedral and mantled with magnetite which in turn is mantled with chlorite. Magnetite occurs along curved cracks in olivine. Reaction rims appear wider in areas of contact with nepheline. Apatite is euhedral, prismatic and poikilitic in pyroxene.

Reference No. 1310
Sample No. HK5-292-317A

Olivine-bearing essexite.

Fine to medium grained, massive, equigranular, hypidiomorphic. Plagioclase (An 44-45) forms anhedral, tabular grains, interlocking with each other and interstitial to pyroxene and nepheline. Grains are generally clear and have turbid rims. Clinopyroxene forms anhedral to subhedral grains, which are interlocking, and may contain small grains of poikilitic magnetite. Nepheline is relatively fresh, blocky, and may enclose apatite and olivine. Nepheline is interstitial to pyroxene and anhedral to euhedral in form. Edges are sometimes turbid from alteration. Amphibole is minor anhedral, interstitial and pleochroic in yellow and brown. Amphibole partially encloses nepheline, plagioclase, clinopyroxene and olivine. Magnetite occurs as an alteration of olivine and as tiny grains in pyroxene. Traces of chlorite and amphibole occur along margins of poikilitic grains. Biotite is anhedral, red-brown, and interstitial. Apatite is euhedral, prismatic and poikilitic in clinopyroxene and nepheline. Olivine forms anhedral grains with

fine-grained magnetite along edges and curved fractures. Chlorite rims the magnetite that occurs along the edge of the olivine grains. Reaction rims are well developed. Olivine is poikilitically enclosed in nepheline and clinopyroxene.

Reference No. 1311
Sample No. HK6 480-505A

Amphibole nepheline syenite.

Medium grained, massive, equigranular, hypidiomorphic. Minor apatite is poikilitic in amphibole, anhedral and prismatic. Amphibole is brown to green-brown with edges altering to fine-grained disseminated magnetite and pale brown biotite. Some twinning is present and grains are subhedral to euhedral in form. Nepheline is almost totally altered with rare relicts of fresh nepheline. Nepheline is altered to very fine-grained fibrous zeolite(?). Rounded blebs are partially enclosed in perthite. Rare fresh relicts are subhedral to euhedral in form. Analcite is anhedral, interstitial and flecked with fibrous zeolitic alteration. Perthite is a stringy perthite; Carlsbad twinning is present. It is slightly turbid, with scattered flecks of saussurite.

Reference No. 1312
Sample No. HK6 480-505B

Nepheline syenite.

Medium to coarse grained, massive, equigranular, hypidiomorphic. Nepheline is anhedral to subhedral and totally altered to fibrous zeolite(?). Nepheline is partially enclosed in perthite. A former mafic mineral is altered to fibrous amphibole, carbonate, disseminated magnetite and biotite. Perthite is stringy, turbid and shows traces of albite along some edges; it contains some sericite and carbonate flecks and some carbonate along fractures.

Reference No. 1313
Sample No. HK6 480-505C

Pyroxenite.

Medium grained, equigranular, massive, allotriomorphic, with curved to straight grain boundaries. Apatite is euhedral, prismatic, poikilitic in magnetite, pyroxene, and amphibole; larger grains are fractured. Magnetite is anhedral, subhedral, disseminated, and rimmed with very fine-grained biotite reaction rims. Clinopyroxene is colourless, anhedral to subhedral; some is twinned. Pyroxene is extensively fractured and veined with very fine-grained alteration of biotite, and carbonate(?). An unknown, probably mafic mineral, possibly interstitial, is totally altered to biotite, fibrous amphibole and magnetite. Amphibole is anhedral, pleochroic in yellow-brown; it occurs interstitial to pyroxene and as isolated patches on edges of pyroxene.

TABLE A-2. MAJOR ELEMENT ANALYSES (WEIGHT PERCENT) OF WHOLE-ROCK SAMPLES FROM THE HECLA-KILMER ALKALIC ROCK COMPLEX.

	Nepheline Syenite						
Ref. No.	1293	1294	1295	1296	1298	1299	1311
SiO_2	50.21	51.25	50.93	51.37	53.62	48.47	52.85
Al_2O_3	22.57	21.75	21.86	22.88	21.55	22.17	22.29
Fe_2O_3	1.71	1.75	1.88	1.23	1.14	2.91	2.30
FeO	3.06	2.25	3.06	2.17	2.42	2.25	1.61
MgO	0.86	0.61	0.81	0.83	0.49	2.08	1.21
CaO	3.86	4.14	3.89	2.63	3.12	2.63	3.21
Na_2O	4.08	4.88	5.41	5.71	5.44	5.65	5.21
K_2O	6.33	6.67	5.69	5.91	6.00	5.14	5.58
TiO_2	0.30	0.25	0.36	0.18	0.31	0.33	0.29
P_2O_5	0.16	0.11	0.25	0.10	0.17	0.17	0.15
S	0.39	0.15	0.14	0.03	0.08	0.02	0.02
MnO	0.14	0.16	0.18	0.10	0.14	0.16	0.17
CO_2	2.06	1.60	2.96	3.11	2.06	2.78	2.00
H_2O+	2.15	2.49	2.36	1.63	1.84	3.14	2.93
H_2O-	0.88	0.85	0.91	0.90	0.85	1.00	0.58
Total	98.80	98.90	100.70	98.80	99.20	98.90	100.40
L.O.I.	6.00	5.70	6.10	5.10	5.00	5.20	4.30

	Nepheline Syenite	Pyroxenite		Ijolite			Essexite
Ref. No.	1312	1297	1313	1301	1300	1302	1303
SiO_2	50.87	34.38	32.84	32.90	35.10	35.70	41.86
Al_2O_3	23.85	7.91	7.94	8.05	7.18	8.65	13.76
Fe_2O_3	1.42	9.13	9.32	18.21	17.35	12.71	3.63
FeO	1.93	7.33	8.45	8.37	7.97	9.18	6.60
MgO	0.54	10.97	10.67	6.91	8.09	7.31	8.76
CaO	3.60	16.96	16.33	12.70	14.20	13.8	11.63
Na_2O	5.63	0.99	1.29	1.40	1.22	1.46	2.39
K_2O	5.28	1.68	1.66	1.67	1.36	1.77	3.25
TiO_2	0.21	3.89	4.20	2.84	2.65	2.03	1.21
P_2O_5	0.11	2.20	1.96	0.40	0.31	0.23	1.06
S	0.04	0.47	0.43	0.90	0.90	0.90	0.15
MnO	0.15	0.22	0.22	1.11	1.14	0.93	0.24
CO_2	1.84	2.62	2.12	1.51	1.18	2.20	1.72
H_2O+	3.53	0.30	0.69	1.39	1.19	1.43	2.20
H_2O-	0.79	0.72	0.47	0.49	0.43	0.57	0.86
Total	99.80	99.80	98.00	98.80	100.30	98.90	99.30
L.O.I.	6.70	2.80	2.40	2.80	2.20	3.90	5.00

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Ref. No.	Sample No.	Ref. No.	Sample No.
1293	HK2A	1312	HK6 480-505B
1294	HK2B	1297	HK3 280-305
1295	HK2 330-355B	1313	HK6 480-505C
1296	HK2 330-355A	1301	HK704 155-180A
1298	HK3 430-455A	1300	HK704 405-430A
1299	HK3 430-455B	1302	HK704 405-430B
1311	HK6 480-505A	1303	HK704 455-480

TABLE A-2. CONTINUED.

	Essexite						
Ref. No.	**1304**	**1305**	**1306**	**1307**	**1308**	**1309**	**1310**
SiO_2	42.32	41.99	43.28	42.94	42.58	43.16	43.24
Al_2O_3	13.93	16.54	15.65	15.81	14.65	14.83	15.05
Fe_2O_3	3.67	3.04	3.64	2.99	3.47	2.96	3.26
FeO	7.08	6.84	6.68	7.00	6.76	7.57	7.08
MgO	7.96	6.84	8.00	7.54	8.30	8.46	8.37
CaO	12.13	10.47	11.99	11.48	11.45	11.82	11.41
Na_2O	2.71	5.90	3.21	3.72	3.66	3.79	4.50
K_2O	2.11	2.17	1.99	1.97	2.23	1.94	2.06
TiO_2	1.24	1.08	1.11	1.14	1.14	1.15	1.11
P_2O_5	1.01	0.93	0.88	0.91	0.83	0.94	0.86
S	0.06	0.05	0.06	0.06	0.12	0.05	0.05
MnO	0.24	0.22	0.23	0.23	0.23	0.24	0.23
CO_2	1.86	0.88	1.48	1.37	1.83	0.82	0.78
H_2O+	1.98	0.90	2.01	2.03	0.29	1.57	1.22
H_2O-	0.68	0.43	0.61	0.56	0.53	0.40	0.40
Total	99.00	98.30	100.80	99.80	98.10	99.70	99.60
L.O.I.	2.80	0.60	2.40	2.20	3.70	1.70	1.50

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Ref. No.	Sample No.	Ref. No.	Sample No.
1304	HK704 455-480A	1308	HK5 267-292A
1305	HK5 217-242	1309	HK5 267-292B
1306	HK5 217-242A	1310	HK5 292-317A
1307	HK5 217-242B		

TABLE A-3. TRACE ELEMENT ANALYSES (PPM) OF WHOLE-ROCK SAMPLES FROM THE HECLA-KILMER ALKALIC ROCK COMPLEX.

	Nepheline Syenite						
Ref. No.	**1293**	**1294**	**1295**	**1296**	**1298**	**1299**	**1311**
Ag	<1	<1	<1	<1	<1	<1	<1
Au							
As							
Ba	1400	1500	1700	1700	1600	1000	1300
Be	7	6	7	7	6	7	6
Bi							
Co	7	10	10	7	8	8	5
Cr	<5	<5	<5	<5	5	<5	5
Cu	8	15	16	5	7	6	6
Ga	15	15	15	7	15	15	15
Hg							
Li	165	95	70	80	60	65	35
Mn							
Mo	25	7	7	4	10	5	9
Nb	150	300	250	100	400	300	250
Ni	<5	<5	<5	<5	<5	<5	<5
Pb	40	105	55	30	75	20	30
Rb	130	160	160	120	130	130	150
Sb							
Sc	<5	<5	<5	<5	<5	<5	<5
Sn	<3	<3	<3	<3	<3	<3	<3
Sr	1000	700	1000	600	800	900	1700
Ti							
V	<10	<10	<10	<10	<10	<10	<10
Y	40	30	40	20	40	300	30
Zn	30	35	109	30	70	95	80
Zr	200	300	200	150	500	800	200
La	250	150	200	<100	200	200	150
Nd	<100	<100	<100	<100	100	<100	<100
Ce	280	240	260	150	260	280	210

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Ref. No.	Sample No.	Ref. No.	Sample No.
1293	HK2A	1298	HK3 430-455A
1294	HK2B	1299	HK3 430-455B
1295	HK2 330-355B	1311	HK6 480-505A
1296	HK2 330-355A		

TABLE A-3. CONTINUED.

	Nepheline Syenite	Pyroxenite		Ijolite			Essexite
Ref. No.	**1312**	**1297**	**1313**	**1301**	**1300**	**1302**	**1303**
Ag	<1	<1	<1	<1	<1	<1	<1
Au							
As							
Ba	1100	1000	1100	530	720	390	2100
Be	8	4	4	10	8	9	6
Bi							
Co	6	60	70	55	60	80	45
Cr	<5	375	390	355	810	445	285
Cu	6	45	50	110	120	220	60
Ga	15	15	15	15	10	10	10
Hg							
Li	60	20	20	20	10	10	95
Mn							
Mo	5	2	<1	4	5	5	4
Nb	250	<30	<30	1500	900	800	200
Ni	<5	70	90	250	210	385	145
Pb	15	15	<10	45	30	34	15
Rb	190	30	40	40	30	40	90
Sb							
Sc	<5	20	25	15	20	9	15
Sn	<3	2	2	5	5	20	<3
Sr	550	600	600	1000	1000	1000	1500
Ti							
V	<10	300	300	200	150	150	150
Y	40	30	40	100	70	70	40
Zn	40	130	140	685	565	460	110
Zr	200	200	250	600	600	600	200
La	250	<100	<100	500	300	300	<100
Nd	<100	150	<100	300	250	300	<100
Ce	250	780	810	1810	410	990	310

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Ref. No.	Sample No.	Ref. No.	Sample No.
1312	HK6 480-505B	1300	HK704 405-430A
1297	HK3 280-305	1302	HK704 405-430B
1313	HK6 480-505C	1303	HK704 455-480
1301	HK704 155-180A		

TABLE A-3. CONTINUED.

	Essexite						
Ref. No.	1304	1305	1306	1307	1308	1309	1310
Ag	<1	<1	<1	<1	<1	<1	<1
Au							
As							
Ba	2000	1600	2000	1800	2100	1500	1600
Be	4	3	4	4	5	4	4
Bi							
Co	40	40	40	40	40	40	40
Cr	285	260	300	285	335	355	335
Cu	60	55	65	60	65	55	55
Ga	10	9	10	10	10	10	10
Hg							
Li	65	20	25	30	55	20	15
Mn							
Mo	3	2	4	7	15	3	4
Nb	200	150	150	150	150	150	100
Ni	140	135	145	145	155	165	165
Pb	10	15	15	10	15	10	<10
Rb	50	50	40	50	80	50	50
Sb							
Sc	15	15	20	20	20	20	20
Sn	<3	<3	<3	7	<3	<3	<3
Sr	2000	1700	3000	3000	2000	1700	1700
Ti							
V	150	150	150	150	150	150	150
Y	30	30	30	40	30	25	40
Zn	110	100	105	100	105	105	105
Zr	250	200	200	200	200	200	150
La	100	100	100	150	100	<100	<100
Nd	<100	<100	<100	<100	<100	<100	<100
Ce	340	320	360	350	330	320	310

Notes: For sample descriptions, see Table A-1. Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto.

Ref. No.	Sample No.	Ref. No.	Sample No.
1304	HK704 455-480A	1308	HK5 267-292A
1305	HK5 217-242	1309	HK5 267-292B
1306	HK5 217-242A	1310	HK5 292-317A
1307	HK5 217-242B		

TABLE A-4. NORMATIVE MINERALS (CIPW NORM) FOR WHOLE-ROCK SAMPLES FROM THE HECLA-KILMER ALKALIC ROCK COMPLEX.

	Nepheline Syenite						
Ref. No.	**1293**	**1294**	**1295**	**1296**	**1298**	**1299**	**1311**
S.G.	2.61	2.56	2.58	2.54	2.55	2.58	2.56
AP	0.397	0.272	0.596	0.241	0.418	0.416	0.367
PO	1.144	0.438	0.394	0.085	0.232	0.058	0.058
IL	0.610	0.506	0.702	0.355	0.623	0.661	0.580
OR	40.055	42.018	34.573	36.326	37.579	32.088	34.786
AB	21.121	16.265	39.798	44.339	29.688	42.353	31.803
AN	19.366	18.879	-1.079	-7.552	15.211	-5.952	15.749
C	2.532	0.0	7.377	10.130	0.886	9.894	2.317
AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MT	2.652	2.702	2.800	1.853	1.750	4.453	3.515
HM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DI	0.0	0.877	0.0	0.0	0.0	0.0	0.0
FO	1.606	0.849	1.452	1.505	0.905	3.831	2.226
FA	1.955	1.203	2.563	2.194	2.389	1.139	0.660
NE	8.564	15.009	3.912	3.176	10.319	4.387	7.939
LC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HE	0.0	0.983	0.0	0.0	0.0	0.0	0.0
CC	0.0	0.0	6.913	7.348	0.0	6.671	0.0
RU	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LN	0.0	0.0	0.0	0.0	0.0	0.0	0.0

S.G. - Specific Gravity; AP - Apatite; PO - Pyrrhotite; IL - Ilmenite;
OR - Orthoclase; AB - Albite; AN - Anorthite; C - Corundum; AC - Acmite;
MT - Magnetite; HM - Hematite; WO - Wollastonite; EN - Enstatite; FS - Ferrosilite;
Q - Quartz; DI - Diopside; FO - Forsterite; FA - Fayalite; NE - Nepheline;
LC - Leucite; KP - Kaliophilite; HE - Hedenbergite; CC - Calcite; RU - Rutile;
NS - Na_2SiO_3; KS - Kalsilite; CR - Chromite; LN - Larnite
Note: For sample descriptions, see Table A-1.

Ref. No.	Sample No.	Ref. No.	Sample No.
1293	HK2A	1298	HK3 430-455A
1294	HK2B	1299	HK3 430-455B
1295	HK2 330-355B	1311	HK6 480-505A
1296	HK2 330-355A		

TABLE A-4. CONTINUED.

	Nepheline Syenite	Pyroxenite		Ijolite			Essexite
Ref. No.	1312	1297	1313	1301	1300	1302	1303
S.G.	2.54	3.30	3.31	3.39	3.42	3.27	2.94
AP	0.273	5.180	4.677	0.976	0.741	0.566	2.603
PO	0.117	1.308	1.213	2.597	2.543	2.619	0.435
IL	0.426	7.499	8.205	5.676	5.187	4.091	2.433
OR	33.363	6.831	0.0	1.261	1.177	0.0	12.312
AB	26.648	0.0	0.0	0.0	0.0	0.0	0.0
AN	18.310	12.357	11.282	11.308	10.404	12.541	18.219
C	2.764	0.0	0.0	0.0	0.0	0.0	0.0
AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MT	2.199	9.818	13.035	16.698	15.692	19.556	5.571
HM	0.0	2.496	0.596	7.647	7.085	0.0	0.0
WO	0.0	0.0	0.0	0.862	1.076	1.119	0.0
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DI	0.0	32.399	32.176	39.061	44.783	41.562	22.248
FO	1.007	8.907	8.700	0.0	0.0	0.035	8.954
FA	1.764	0.0	0.0	0.0	0.0	0.002	3.145
NE	13.130	4.606	6.082	6.753	5.762	7.101	11.595
LC	0.0	2.553	7.919	7.162	5.577	8.711	6.302
KP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HE	0.0	0.0	0.0	0.0	0.0	2.052	6.182
CC	0.0	6.046	4.958	0.0	0.0	0.0	0.0
RU	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LN	0.0	0.0	1.156	0.0	0.0	0.044	0.0

Note: For sample descriptions, see Table A-1.

Ref. No.	Sample No.	Ref. No.	Sample No.
1312	HK6 480-505B	1300	HK704 405-430A
1297	HK3 280-305	1302	HK704 405-430B
1313	HK6 480-505C	1303	HK704 455-480
1301	HK704 155-180A		

TABLE A-4. CONTINUED.

				Essexite			
Ref. No.	**1304**	**1305**	**1306**	**1307**	**1308**	**1309**	**1310**
S.G.	3.03	2.98	3.00	2.99	2.96	3.02	3.02
AP	2.481	2.246	2.111	2.204	2.019	2.251	2.052
PO	0.174	0.143	0.170	0.172	0.345	0.142	0.141
IL	2.494	2.136	2.180	2.261	2.270	2.254	2.169
OR	13.216	8.710	12.173	12.168	13.832	11.844	12.536
AB	3.996	0.0	4.318	4.184	1.261	2.086	0.661
AN	20.766	12.740	23.180	21.533	17.780	18.290	15.206
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MT	5.635	4.589	5.458	4.527	5.276	4.430	4.863
HM	0.0	0.0	0.0	0.0	0.0	0.0	0.0
WO	0.0	0.0	0.0	0.0	0.0	0.0	0.0
EN	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Q	0.0	0.0	0.0	0.0	0.0	0.0	0.0
DI	21.339	19.767	19.531	18.265	21.952	20.631	22.003
FO	7.777	6.006	8.093	7.807	8.057	8.535	7.880
FA	3.511	3.291	3.406	3.978	3.264	4.374	3.623
NE	10.988	28.154	12.876	15.538	16.907	16.798	20.861
LC	0.0	3.649	0.0	0.0	0.0	0.0	0.0
KP	0.0	0.0	0.0	0.0	0.0	0.0	0.0
HE	7.622	8.569	6.503	7.364	7.036	8.365	8.005
CC	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RU	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CR	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LN	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Note: For sample descriptions, see Table A-1.

Ref. No.	Sample No.	Ref. No.	Sample No.
1304	HK704 455-480A	1308	HK5 267-292A
1305	HK5 217-242	1309	HK5 267-292B
1306	HK5 217-242A	1310	HK5 292-317A
1307	HK5 217-242B		

TABLE A-5. AVERAGE CHEMICAL COMPOSITIONS (WEIGHT PERCENT AND PPM) OF LITHOLOGIC UNITS FOR THE HECLA-KILMER ALKALIC ROCK COMPLEX.

	Nepheline Syenite (N = 8)		Pyroxenite (N = 2)	
	Mean	Std. Deviation	Mean	Std. Deviation
SiO_2	51.20	1.57	33.61	1.09
Al_2O_3	22.37	0.74	7.93	0.02
Fe_2O_3	1.79	0.59	9.23	0.13
FeO	2.34	0.51	7.89	0.79
MgO	0.93	0.52	10.82	0.21
CaO	3.38	0.58	16.65	0.45
Na_2O	5.25	0.55	1.14	0.21
K_2O	5.82	0.51	1.67	0.01
TiO_2	0.28	0.06	4.05	0.22
P_2O_5	0.15	0.05	2.08	0.17
MnO	0.15	0.02	0.22	0.00
CO_2	2.30	0.56	2.37	0.35
S	0.11	0.12	0.45	0.03
H_2O+	2.51	0.65	0.50	0.28
H_2O-	0.84	0.12	0.60	0.18
LOI	5.51	0.76	2.60	0.28
TOTAL	99.44	0.77	98.90	1.27
S.G.	0.00	0.00	0.00	0.00
Ag	<1.00	0.00	<1.00	0.00
Ba	1412.50	264.24	1050.00	70.71
Co	7.62	1.77	65.00	8.49
Cr	<2.50	4.63	383.50	9.19
Cu	8.50	4.14	47.50	3.54
Li	78.50	38.88	19.00	1.41
Ni	<5.00	0.00	79.50	13.44
Pb	45.37	31.07	3.00	18.38
Zn	60.37	32.09	135.00	9.90
B				
Be	6.75	0.71	4.00	0.00
Mo	9.00	6.78	0.50	2.12
Sc	<5.00	0.00	22.50	3.54
Sr	906.25	362.96	600.00	0.00
V	<10.00	0.00	300.00	0.00
Y	67.50	94.23	35.00	7.07
Ga	14.00	2.83	15.00	0.00
Nb	250.00	92.58	<30.00	0.00
Rb	146.25	23.26	35.00	7.07
Zr	318.75	223.51	225.00	35.36
Sn	<1.75	2.31	2.00	0.00
Eu	<100.00	0.00	<100.00	0.00
Yb	1.12	0.99	2.00	0.00
Ce	241.25	43.24	795.00	21.21
La	162.50	112.60	<100.00	0.00
Nd	<75.00	70.71	25.00	176.78

TABLE A-5 . CONTINUED.

	Ijolite (N = 3)		Essexite (N = 8)	
	Mean	Std. Deviation	Mean	Std. Deviation
SiO_2	34.57	1.47	42.67	0.57
Al_2O_3	7.96	0.74	15.03	0.95
Fe_2O_3	16.09	2.96	3.33	0.31
FeO	8.51	0.62	6.95	0.31
MgO	7.44	0.60	8.03	0.61
CaO	13.57	0.78	11.55	0.51
Na_2O	1.36	0.12	3.74	1.10
K_2O	1.60	0.21	2.21	0.43
TiO_2	2.51	0.42	1.15	0.05
P_2O_5	0.31	0.09	0.93	0.08
MnO	1.06	0.11	0.23	0.01
CO_2	1.63	0.52	1.34	0.46
S	0.90	0.00	0.08	0.04
H_2O+	1.34	0.13	1.52	0.67
H_2O-	0.50	0.07	0.56	0.16
LOI	2.97	0.86	2.49	1.37
TOTAL	99.33	0.84	99.32	0.87
S.G.	0.00	0.00	0.00	0.00
Ag	<1.00	0.00	<1.00	0.00
Ba	546.67	165.63	1837.50	244.58
Co	65.67	13.32	41.87	0.64
Cr	536.33	241.14	305.62	32.33
Cu	151.33	59.68	59.50	4.78
Li	14.00	3.46	40.37	29.05
Ni	281.67	92.88	148.50	11.16
Pb	39.33	8.14	10.00	8.32
Zn	570.00	112.58	104.87	3.31
B	15.00	5.00		
Be	9.00	1.00	4.25	0.89
Mo	4.67	0.58	5.25	4.20
Sc	14.67	5.51	18.12	2.59
Sr	1000.00	0.00	2075.00	594.62
V	166.67	28.87	150.00	0.00
Y	80.00	17.32	33.12	5.94
Ga	11.67	2.89	9.87	0.35
Nb	1066.67	378.59	156.25	32.04
Rb	36.67	5.77	57.50	17.53
Zr	600.00	0.00	200.00	26.73
Sn	10.00	8.66	0.12	3.72
Eu	<100.00	0.00	<100.00	0.00
Yb	7.67	2.08	2.12	0.35
Ce	1070.00	703.42	330.00	18.52
La	366.67	115.47	31.25	109.99
Nd	283.33	28.87	<100.00	0.00

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